

Towards a taxonomy of innovation systems

Manuel Mira Godinho
(ISEG/UTLisbon and CISEP, mgodinho@iseg.utl.pt)

Sandro F. Mendonça
(ISCTE and SPRU, sfm@iscte.pt)

Tiago Santos Pereira
(CES and CISEP, tsp@ces.uc.pt)

Preliminary draft: please do not quote

Abstract: The concept of National Innovation System (NIS) has been recently applied in the context of developing nations even though it was originally developed in relation to the more developed economies (Japan, Scandinavian countries, US etc.). This raises the methodological problem of knowing whether what was learnt in the study of more advanced NISs is relevant for all sorts of economies regardless the maturity of their actual innovation systems. With this question in mind an exploratory exercise is implemented. First a technique for mapping different NIS is put forward and next based on such mapping a taxonomy of NISs is proposed. The technique although simple in the steps it requires shows analytical potential. The cartography it generates allows one to compare directly different countries, by visualizing in bi-dimensional space the graphic pattern of the relevant dimensions of their respective NISs. This technique is applied to 69 countries (87.4% of the world population) and a set of 29 indicators is used to examine these NISs along eight major dimensions. With the resulting data, and with the help of cluster analysis, a taxonomy of innovation systems is proposed. That taxonomy which contains 6 major types of NISs indicates that what differentiates most the individual systems is their performance in three critical dimensions: innovation, diffusion and basic and applied knowledge. Country size and the natural resources endowment of the economies also emerge as important contingency factors underlying the overall dynamics of different NISs.

Key Words: innovation, national innovation systems, economic development

1. Introduction

The aim of this paper is to put forward a taxonomy of national innovation systems (NISs). With that purpose in mind we will first implement a technique for mapping innovation systems that was developed by Godinho et al. (2003). Such mapping allows one to compare directly different NISs, by visualizing in bi-dimensional space the graphic pattern of the relevant dimensions of each innovation system. Next the quantitative output of this NISs mapping will be used as the basis for performing a cluster analysis in a second step. The resulting country groupings will be analysed for identifying the major factors separating different NISs types. This will be the basis for a definition of a possible NISs taxonomy.

In the paper eight major dimensions along which innovation systems develop are highlighted. These dimensions include market conditions; institutional conditions; intangible and tangible investments; basic and applied knowledge; external communication; diffusion; and innovation. For materialising such eight NIS dimensions 29 individual indicators were selected for a total of 69 countries. These countries range from the most developed and largest economies in the world, through the emerging economies, to the less advanced developing countries. For each of the 8 relevant NIS dimensions between 2 and 6 of these 29 indicators were allocated. The definition of the NIS dimensions and the selection of indicators tried to respect theoretical and logic criteria of organization of the data.

Overall the data basis that was developed and the methodological steps that were taken represent a unique attempt to cover such a large and diverse number of countries with the aim of analysing their behaviour in terms of creating, consolidating and advancing their national innovation systems. As it will be shown, the resulting outcomes of this paper have empirical, theoretical and normative potential.

Following this introduction the paper is divided into five main sections. Section 2 presents the conceptual context of the mapping and taxonomisation exercise that will be carried out. In section 3 the method followed is described, with information about the observed NIS dimensions, about the variables aggregated into each of those dimensions and about the economies that were selected as well. Next section 4 presents the results

of the empirical analysis, by concentrating first on the mapping of the individual NISs and then on the structure that stems from a cluster analysis. The clusters that emerged are observed thoroughly in section 5, providing an interpretation for the contrasting positions of the different countries involved in this exercise. Finally, the concluding section attempts at a generalization based on the analyses of the previous sections, suggesting a possible taxonomy of national innovation systems.

2. The NIS perspective

The NIS concept has been used as a “focusing device” in bringing forward the interdependent and distributed features of innovation. The concept was developed in the 1980s and has since had a very significant impact, both in innovation studies and in policy arenas.

This section explores the NIS concept by analysing its evolution since the 1980s. The understanding that emerged in the innovation literature is discussed, and the barriers that still restrain its translation into quantitative analyses are considered. Finally, the adequacy of using it in the context of less developed economies is discussed, namely taking into consideration the profusion of recent work in this perspective in many developing countries.

2.1 The qualitative dimensions of innovation

In the economics of technical change the acknowledgement of the systemic nature of the innovation process represents a key claim in favour of considering the interactive and historical nature of the innovation phenomenon. Such claim however embodies a methodological option. The systems approach assumes that the appreciation of the evolution of countries’ technological capabilities and performances makes these quite complex objects of analysis, one cannot understand the picture without the detail. Consequently, this stands in contrast with traditional growth accounts, which take statistical aggregates as the privileged source of empirical information. The NIS

approach follows an alternative path, the awareness of concrete institutions and varieties in macroeconomic environments are at the centre stage.

This NIS concept was initially put forward as a qualitative concept for describing the technological, economic, social and institutional dimensions of innovation in advanced economies. Freeman (1987) deployed it in his discussion of the Japanese innovation system, while Lundvall (1985, 1992) and others firstly applied it in connection to the empirical observation of the interactions and institutional framework that support innovative activities in the Scandinavian economies. From these initial applications, the concept was rapidly generalised to all the most advanced economies, being Nelson's 1993 book a good example of this.

In spite of a relative variation in the definition of NIS (see Niosi, 2002) the major contributions are convergent in highlighting the interactions between firms and institutions as well as noting the path-dependent character of those relations. Further, that variation can even be justified for ontological reasons: the historic nature of the object does not allow for a single definition of innovation system. As claimed by Lundvall (2004) "to develop 'a general theory' of innovation systems that abstracts from time and space would therefore undermine the utility of the concept both as an analytical tool and as a policy tool".

Assuming that variation on the understanding of 'innovation system', the approach has developed significantly since its inception, and several associated concepts have emerged stressing different aspects of the innovation systems dynamics. Some of these derived concepts refer to sub-national realities, such as in the work of Saxenian (1994) that dealt with the local conditions in Massachusetts' Route 128 or in Silicon Valley, or in the work of Cooke (1998), Braczyk (1998), Landabaso (1995) or Asheim and Gertler (2004) that refer to "regional innovation systems" in the European context. In contrast, other approaches that derive from the initial NIS concept refer to realities which are supra-national or that simply are not geographical in their nature. That is the case of the "sectoral systems of innovation" approach (Breschi and Malerba 1997, Malerba 2004), that stresses the opportunity and appropriability conditions in different sectors as key factors in determining specific cumulativeness paths, or also the case of the

“technological innovation systems” approach (Carlsson et al. 1995 and 1997) that focuses on generic technologies with general application over many industries.

All these developments of the original concept can be seen as evidence that research on innovation has tried to capture the manifold dimensions of innovative phenomena. However, in this paper our interest is not on how each of those derived concepts developed and acquired its own place in the innovation literature. Rather we are interested in the original concept and our analysis is centred on the national level, with the objective of promoting a cartography of NISs development and characteristics.

In doing this we have to pay attention to the fact that the NIS concept was initially put forward as a qualitative construction. It came somewhat before in time than many of the most recent technological developments, but it is clear that it was already put forward in connection to the central characteristics of the present competitive regime. It was not by chance that the concept emerged in the late 1980s when the signs of a new techno-economic paradigm were already clear, with a set of radically new technologies starting to diffuse economy-wide (Freeman and Perez 1988, Freeman and Soete 1997). A key feature that has differentiated the new paradigm from the previous ones is precisely the permanence and ubiquity of innovation, which evolved from a relatively discrete and limited occurrence to a much more pervasive aspect of economic life. In the new paradigm firms must be involved, more than ever, in continuous innovation to remain competitive. In this process firms allocate a greater share of their resources to the internal production and combination of knowledge and to the external tapping of other sources, including the research organizations and their competitors (Autio et al. 1995). National governments have also been part of this process, by strengthening the S&T infrastructure (Teubal et al. 1996, Rush et al. 1996) and by trying to improve the regulatory framework and more generally the institutional conditions affecting innovation. These developments have led to what many have classified as the “knowledge based economy” (OECD 2000) or, in a relatively more dynamic interpretation, to the “learning economy” (Lundvall and Borràs 1999, Gregersen and Johnson 2001).

Summing up, innovation is central to understanding the competitive dynamics in contemporary economies. It emerges from new combinations of knowledge and

depends on the institutional arrangements prevailing in each society, making it an essentially qualitative process.

2.2 How far can we go in the quantitative analyses of NISs?

It is that qualitative nature of innovation that defies quantification. At least two recent developments can be considered as weakening the barriers to a possible quantification. Firstly, we might refer to the emergence and wide use of several new innovation indicators and sources. As it is known significant advancements have been made in the field of innovation measurement recently, through the implementation of a variety of new indicators. This has happened since the early 1990s when a new generation of innovation indicators has been established, adding to the classical “input” and “output” indicators. A significant part of this new generation of indicators stems from the process associated with the publication of the “Oslo Manual” (OECD 1992, Smith 1992) and to the subsequent setting up of several innovation surveys, being the most prominent the three CIS inquiries implemented by EUROSTAT in collaboration with several national statistical offices. From the studies that have been produced with these CIS-based indicators, it is clear that several dimensions of the innovation process which could not be previously studied can now be approached and understood by using quantitative data and analysis (Smith 2004, Evangelista et al. 1998). Another component of this new generation of indicators is more recent yet, and relates to the establishing by the OECD, the EU and other international organizations of statistics trying to reflect the diffusion of ICTs and other related technologies. Besides this new generation the most recent period has also witnessed to the creation and intense use, by both the academic and the policy-making communities, of several other indicators built up from the more “classic” bibliometric, patent, trademark and R&D statistics (Mendonça, Pereira and Godinho 2004).

The second recent development that can be seen as favouring the type of exercise we will be undertaking in the following sections relates to a demand-side effect. Policy-makers have been asking their advisers and researchers too for supplying them with summary measures of their countries’ and regions’ relative innovation status. This is part of a more general benchmarking movement, and in the area of innovation the most

notable result has been the production of “innovation scoreboards”.¹ This type of exercise has been criticized for tending to reduce the multidimensionality of innovation processes to just one simple summary measure. Such scoreboards «can provide useful information for macro level policies [...], but a scoreboard is of less value as one moves to the meso and micro level, where firms are active and where most policy actions occur» (Arundel 2001). From this and other similar criticisms that have been put forward we can conclude that while the summarizing need remains, excessive simplification shall be avoided in the finding of solutions.

2.3. The NIS concept within the developing countries context

As pointed out above, the NIS concept emerged in the late 1980s and in the 1990s in the context of research focusing on more advanced economies. More recently however this concept has been applied more widely to the developing and intermediate economies with several studies emerging focusing on different countries in Asia (China, e.g. Gu, 1997; India, e.g. Krishnan, 2003; Thailand, e.g. Intarakumnerd, 2004; or Vietnam, e.g. Sinh, 2004) and Latin America (Brazil, e.g. Cassiolato *et al.*, 2003; Mexico, e.g. Cimoli, 2003).

In a sense this new trend may be interpreted as a return to the origins. In the light of pioneering material by Chris Freeman (2004) originally written in the early eighties but only recently made available, the concept of national innovation system arose from the analysis of the historical factors behind the stunning economic development of countries like Germany and Japan that were well behind the technological frontier in the late 19th and early 20th centuries. As Lundvall (2004) notes in his introduction to Freeman’s paper, the Listian emphasis on governmental initiatives to build a technological infrastructure as well as the importance attributed to the coupling between knowledge institutions and firms represents the hallmark of modern research on innovation systems,

¹ In 2000 the EU Lisbon summit decided to develop a European Innovation Scoreboard, which is an example of this approach.

This recent recovery of the NIS concept in the context of the analysis of economic development raises however the methodological problem of knowing whether what was learnt in the study of more advanced NISs is relevant for all sorts of economies regardless the maturity of their actual innovation systems. Such question is particularly relevant for countries in lower and intermediate levels of development seeking to progress to more advanced stages of economic development based upon the promotion of endogenous innovation. Through the technique that will be presented in the next section, we can experimentally test the validity of applying the NIS concept to those economies.

3. The method

The technique we will deploy now is partially based on previous work of Godinho et al. (2003). In that paper an exploratory exercise aiming at mapping different NISs was put forward. Although simple in the steps it required to generate graphical representations and quantitative indicators for each NIS that exercise showed that the method proposed offered some interesting possibilities. The cartography generated by it allowed the direct comparison of countries by visualizing in bi-dimensional space the graphic pattern of the relevant dimensions of their respective NISs. In this way a comparative analysis of weaker and stronger dimensions of each NIS was made possible. Further, as it was shown this analysis could fruitfully be applied to both the more and the less advanced economies. Now we will extend that approach to a much larger number of countries, 69 on the total, and in connection with this a set of 29 indicators will be processed. The objective is moving on from an initial essentially exploratory stage to a more robust work in terms of data collection, processing and analysis. This analytical quest has practical importance for drawing normative implications, namely by illuminating the cognitive and institutional factors that are more relevant for the economies aiming at catching up. As stated above, the purpose of the analysis now is to identify what are the common and differentiating factors of different types of NISs in order to propose a taxonomy of innovation systems.

Next we will briefly describe in 3.1 the proposed technique and how it is based on the decomposition of an innovation system in terms of a set of major dimensions. In sub-

section 3.2 we will present the indicators that were selected to represent each of those major dimensions.

3.1. The NIS “dimensions” and the variables involved in the exercise

The “National Innovation System” concept is a complex model that grew out of the 1970s and 1980s innovation theory advancements that occurred as a reaction to the archaic “linear model”. This means that many of the analytical perspectives stemming from previous models of innovation, from the interactive vision of S&T-push and demand-pull factors (Freeman 1979) to the chain-link perspective of innovation (Kline and Rosenberg 1986) are now in practice part of the broader NIS theoretical framework. However, the NIS model goes much further than these previous approaches, since it concentrates not just on a few actors and local processes that lead to the emergence of single innovations, but it proposes a much wider view of a system with a large diversity actors, institutions and interactive arrangements that push forward structural change in the economies and societies.

This complex perspective enclosed in the NIS concept is at odds with many simplifying graphical representations of the national innovation system that have emerged. Those representations, by focusing just on the different types of actors and the possible connections between them, overlook a multiplicity of other aspects that are enclosed in the NIS theorisation.

The technique we are now employing will also generate a graphical representation of NISs, but of a different sort. We will focus on four groups of aspects in the way to mapping and measuring the overall performance of NISs. Those groups are as follows:

- (i) *preconditions for innovation;*
- (ii) *inputs into the system;*
- (iii) *structural organization;*
- (iv) *system outputs.*

In what follows we will elaborate on each of these groups, discussing the NIS dimensions associated with each of them and presenting (in small boxes) the indicators

we consider most appropriate to stand for each dimension. In reading what comes below one must be aware that these NIS dimensions necessarily emerge, in practice, as a compromise between innovation systems theory and the indicators which may be gathered to stand for the different dimensions that underlie the concept of “innovation system”.

(i) Preconditions for innovation

We will consider two sorts of innovation preconditions: first *market conditions* and next *institutional conditions*.

In principle, for producers of tradable goods the global market represents their potential demand. But one knows that transaction costs and innumerable other frictions, related to geographical distance, transport costs or the availability of adequate distribution channels, limit a perfect access to global markets. So, and given the national logic of transportation networks, the easiness of business contacts in national language, etc., the national market still remains in many cases as the most important stimulus for individual firms. One can therefore admit that the larger this national market is, in terms of overall extension, affluence and sophistication, the greater will be the market opportunities for firms to produce and innovate. This is certainly valid mostly for non-tradable products firms, as it is the case of many service industries, but also for many of those firms producing tradable products.

Also important in this view of market and demand conditions is the way consumers are spread in the national space. A territory with low population density will be much more difficult to serve than one where the population is more densely distributed.

Dimension 1 - “*Market conditions*”

- Income per capita
- Overall GDP size
- Population density

A second group of preconditions relates to “institutions”. As stressed above, this is a fundamental insight of innovation systems theory: the historic evolution of social and

economic spaces shapes their institutions; these are relatively stable in time and modify slowly; and the way economic agents behave depends largely on them. But, given their nature, institutions are very difficult to represent by any sort of quantitative indicator. We tried to deal with this by considering three sorts of indicators. Firstly, we took an indicator of income distribution. The assumption is that a more even distribution of income improves the capacity of larger segments of the demand to buy new products. Further, lower values of such indicator might indicate higher levels of political stability and social cohesion, which might be good for innovation to happen. Secondly, we selected an indicator that combines the youth of the population with life expectancy. The former indicates possible adaptability and flexibility in the social fabric, while the latter indicates whether healthy conditions exist for both workers and consumers. Finally, we selected a corruption index as an indicator of possible social and economic (in)effectiveness.

Dimension 2 - “*Institutional conditions*”

- GINI index
- Youth of population
- Life expectancy
- Corruption index

(ii) Inputs into the system

A good supply of inputs is also a precondition for systems functioning well. So, in connection with the contextual factors highlighted above, we will now consider other two sorts of preconditions: “*intangible and intangible investment*” and “*knowledge*”. The first of these factors might be seen as a primary input and the second as an intermediary input (and therefore as an output of the system on its own right) of the innovation system.

We will take three indicators for intangible investment: education expenditures, R&D investment and investment in physical capital. All these indicators are well known but they perform specific functions in our framework. Education expenditures stand for the efforts in preparing younger generations for the future. Such efforts do not have an immediate impact on innovation, though their intensity provides a sign to innovators that

society has a more or less strong commitment in relation to basic knowledge accumulation. The same happens with GERD, even though in relation to this indicator the impacts on innovation clearly happen in a more short-medium-term horizon. In the sense they help promoting general and basic knowledge, both education and R&D investments have a direct impact on the dimension we will be discussing next (*knowledge*). Finally, the overall investment rate in physical capital has yet a more short term impact, facilitating the penetration of innovation through the acquisition of capital goods embodying new technology. This last aspect relates yet with another dimension we will be discussing below (*innovation diffusion*).

Dimension 3 - “Intangible and tangible investment”

- Education expenditures as a percentage of GDP
- Education expenditures per capita
- GERD as a percentage of GDP
- GERD per capita
- Investment rate (GFCF as a percentage of GDP)

“*Knowledge*”, like “*institutions*”, is another dimension that resists to quantification. However it is such a critical dimension of a NIS that we can not avoid dealing with it. Three knowledge levels might be considered: general knowledge, of the type that is acquired through participation in the education system; scientific knowledge; and technologic knowledge. For the first level an indicator of educational attainment was selected. For the other two levels, three indicators were envisaged: scientific publication; number of researchers in the labour force; and tertiary enrolments in S&T subjects. The first indicates the country’s scientific output and provides information of a possible longer term innovation potential. The second, the number of personnel involved in research activities, is correlated to a previous indicator (GERD/GDP), but it is used here in connection with both scientific and technologic knowledge. The last indicator was selected given the difficulty found in identifying an appropriate measure for technologic knowledge. But, in line with what is argued in Fagerberg & Godinho (2004), we admit that the higher the proportion of tertiary students enrolled in technical subjects the stronger the society orientation towards values and behaviours that favour a dynamic technology base.

Dimension 4 - “Knowledge”

- Population with 2+3 Education as a percentage of total population
- Researchers as a percentage of labour force
- Scientific papers per Capita
- Tertiary enrolment in technical subjects as a percentage of the population

(iii) Structural organization

The structural analysis of economies tends to concentrate on the distribution of value added and employment among different sectors. Also the analysis of countries' competitiveness tends to emphasize the specialization composition in terms of the sectoral origin of exports. Further industrial organization analysis focus on yet another structural aspect, the degree of industry concentration, normally analysed in connection to firm size distribution. All these structural levels are the outcome of dynamic competition processes driven mainly by innovation and technological change.

It has been known for long now that the sectoral characteristics of an economy affect the direction, nature and intensity of innovation (Pavitt 1984). To understand well an innovation system behaviour it is pertinent to have information about how the economic activity (production, exports) is distributed among sectors with different R&D and knowledge intensities. In connection to this, and in conformity with the structural levels highlighted in the previous paragraph, one also needs to have information about the size distribution of firms in the economy. This is a sort of information that is very difficult to find for a multi-country sample like ours given the diversity of classification practices that statistical offices follow in relation to firm size. As a proxy we took the sales of the home-based top global 500 R&D-performing companies as a percentage of GDP. Empirical research has stressed the role of this sort of large multinational firms in generating a greater share of global innovative activities (Pavitt and Patel 1988, Patel 1995, Zanfei 2000). Despite the increasing internationalisation of R&D that has gone along the activities of these companies (Meyer-Krahmer et al. 1998) the fact is that they still are the backbone of a great deal of the domestic innovative activities in the countries where they come from.

Dimension 5 - “Economic structure”

- Value Added in High-Tech & Medium High-Tech Activities (%)
- High-Tech & Medium High-Tech Exports (%)
- Sales of home-based top 500 global R&D companies / GDP

A second structural aspect that deserves attention when considering the organization of a NIS has to do with the discussion of the frontiers of each national innovation system and the way it relates outside the national space. It has been discussed whether in an era of globalisation the national level of analysis retains the same relevance it had before. As pointed out above, several arguments (transaction costs in international trade, common infrastructure and culture, national policies...) show that the national level is still relevant for economic and innovation analysis. But, despite that, it is also acknowledged that external communication is essential for the vitality of the innovation system. Such communication is a way of increasing the diversity of stimuli into the innovation system and for bringing in key information and knowledge that lack internally. A good connection to the outside world is therefore essential as a complement to the knowledge generated domestically. The three indicators we propose below provide an adequate account of this dimension.

Dimension 6 - “External communication”

- (Exports + Imports) / GDP
- (Inward + Outward stocks of FDI) / GDP
- Bandwidth in international connections (bits per Capita)

(iv) system outputs

The major outputs of a NIS have naturally to do with the system’s innovation performance but also with “*diffusion*”, i.e. with the circulation and spreading of knowledge and new technologies among the different parts of the system. A major theoretical point that the NIS approach brought to the analysis of the innovation process has precisely to do with this redistributive power of the innovation system (David and Foray 1995). Such power is a direct function of the collaborative arrangements and relatively stable linkages that firms set up with a diversity of actors, ranging from their suppliers (including finance providers), clients and competitors, to the R&D and

intermediate organizations that produce and transfer S&T knowledge to the economy. In the absence of indicators that might provide an account of these interactive patterns in the NIS, we have to rely on more classic indicators of the diffusion of specific innovations. These indicators have however their own merits. The first three are combined into an aggregate indicator of ICT diffusion. The fourth refers to a consumer product technology. The fifth has not been much used, but it seems pertinent since indicates the diffusion of a specific type of innovative practice within the different economies.

Dimension 7 - “Diffusion”

- Personal Computers per capita
- Internet Hosts per capita
- Internet Users per capita
- Cellular Phones per capita
- ISO 9000 + ISO 14000 Certificates per capita

Finally, we focus on the eight critical dimension to account for NISs dynamics: “*innovation*”. The behaviour on this dimension results from the contextual conditions, the resources mobilized and the overall organization of the system. We take here two different indicators for innovation: patenting and trademark activity. The first is a well established innovation indicator. It provides information about the sort of innovation that derives and relates basically to technologic knowledge. The advantages and disadvantages of this indicator are well known. We can admit that the total number of patents granted to each country is a good indicator of innovation propensity and potential performance.

The second indicator, trademark activity, has been recently argued for as an innovation indicator (Mendonça et al. 2004). The idea is that this indicator provides information on the marketing efforts that firms carry out to establish new and differentiated products in the marketplace. The flow of new trademarks (as the flow of new patents) might therefore be understood as an indicator of innovative efforts, in connection to the approach of firms to the demand they are facing.

Dimension 8 - “Innovation”

- US Patents per Capita
- Trademarks per Capita

3.2. Data sources and the process for estimating the basic NIS dimensions

Having defined the eight basic dimensions of the national innovation system, we will now describe briefly the data sources, clarify the construction of the indicators and how they are aggregated into the different dimensions.

Table 1 below identifies the indicators that were kept as representing better each of those dimensions and provides information about the sources and other details related to each indicator. The sources of the data we are using are in almost all cases national and international statistical and regulatory agencies. We sought to retain a diversity of indicators, based on different types of variables (stock and flows, monetary and physical) in order to provide appropriate information about the eight NIS dimensions. We are aware that many of the selected indicators do not constitute optimal solutions for portraying the different dimensions of a NIS. As stated above the selected indicators are a compromise between innovation systems theory and available statistical data. Thus we had to act pragmatically, choosing the indicators according to their accessibility, reliability and adequate coverage of the period to be observed. Fortunately the quantity of data we have now available has no comparison to what existed only 10 or 15 years ago. The Internet has played a fundamental role, making many international statistics readily available on-line. Moreover, some large databases have also been made accessible through other electronic supports such as CD-ROMs.

All together we are using 29 variables for 69 countries.² The period to which the data refers to is normally the years after 2000, with many variables referring to 2002 or 2003, even though a few exceptions exist (for details see table below).

² Amable et al. (1997) proposed an exercise with some aspects in common with the one we are undertaking now. Their analysis involved a larger number of indicators, even though for a much smaller sample (only 12 countries, all of them belonging to the OECD).

Table 1. Variables and Indicators used to determine each NIS dimension

Code	Variable/indicator name (V1-V30) NIS Dimensions (D1-D8)	Source	Year	Construction of the Indicator
D1	Market Conditions			
V1	Gross Income per Capita PPP(US\$)	1/2/11/12	2001/2003	LOG LOG
V2	Population Density per square km	2/3	2001/2003	
V3	GDP (Millions of Dollars)	2/4/5/12	2000/2001/2002	
D2	Institutional Conditions			
V4	Gini Index	5/13/14	1992-2000	Inverse (1/Gini Index) % of Total Population (Male + Female) / 2 Score between 0-10
V5	Youth of the Population (Population Under 15 y.o.)	1/5	2002	
V6	Life Expectancy at Birth	5/10	2002	
V7	Corruption Index	6	2003	
	Notes: V5+V6 aggregated into a single indicator; In the Corruption Index 10 is given to the less corrupt countries			
D3	Investment Climate			
V8	Education Expenditures % of GDP	7/8/15	95-97/2001/2002	Per Capita, LOG
V9	Education Expenditures per Capita	3/7/8/15	95-97/2001/2002	
V10	GERD % of GDP	5/8/14	2000/2001/2002	Per Capita, LOG
V11	GERD per Capita	3/5/8/14	2000/2001/2002	
V12	Investment Rate % of GDP	2/9/4	2001/2002	
	Note: V8+V9 aggregated into a single indicator; V10+V11 aggregated into a single indicator			
D4	Scientific Knowledge			
V13	Population with 2+3 Education % of Total Population	8/14	2001/2002	2+3 / POP
V14	Researchers per Capita (per Million Inhabitants)	8/5/7/14/16/17	1990-2000/2001/2002	
V15	Scientific Papers per Capita (per Million Inhabitants)	18	1998 (a)	
V16	Tertiary Enrolment in Technical Subjects per Capita	19	1998 (a)	
	(a) or latest available year.			
D5	Economic Structure			
V17	Value Added in High-Tech & Medium H. –T. Activities (%)	19	2000 (b)	(c)
V18	High-Tech & Medium High-Tech Exports (%)	19	2000 (b)	(d)
V19	Sales of home-based Top global 500 R&D Companies/GDP	20/2	2001	(e)
	Notes: (b) or latest available year; or latest available year; (c) For Hong Kong – values of 1998 and for D.R. of Congo – values of 1990; (d) Share of medium and high-tech activities in Manufacturing Value-Added* share of Manufacturing Value-Added in GDP; (e) Sum of the worldwide sales of the home-based companies that are part of the ranking of the top 500 global R&D performers as a percentage of the GDP of corresponding country.			
D6	Openness & Absorption			
V20	(Exports + Imports) / GDP	5/14/27	2002	X+M Inward+Outward
V21	(Inward + Outward stock of FDI) / GDP	21/14	2002	
V22	Bandwidth (bits per Capita)	3/22	2002	

(Table continues next page)

Table 1. (continuation from previous page)

Code	Variable/indicator name (V1-V30) NIS Dimensions (D1-D8)	Source	Year	Construction of the Indicator
D7	Diffusion			
V23	Personal Computers per 100 inhabitants	3	2003	ISO 9000+14000/POP
V24	Internet Hosts per 10000 inhabitants	3	2003	
V25	Internet Users per 10000 inhabitants	3	2003	
V26	Cellular Phones per 100 inhabitants	3	2003	
V27	(ISO 9000 + ISO 14000 Certificates) / Population	23/3	2002	
	Note: V23+V24+V25 aggregated into a single indicator			
D8	Innovation			
V28	US Patents per Capita	24/25	2003 (f)	% of Total POP, LOG
V29	Trademarks per Capita	26	2003	% of Total POP, LOG
	Note: (f) For countries with a very few patents an yearly average was calculated, normally between 1997 and 2003.			
	Other Variables (Auxiliary)			
V30	Population 2000 (Millions)	3	2003	

Sources:

1. IMD, World Competitiveness Yearbook 2004
2. World Bank, World Development Report 2003
3. ITU, World Telecommunication Development Report 2003
4. Taiwan Statistical Data Book 2001, Council for Economic Planning and Development, Republic of China
5. UNPD, United Nations Development Program Report 2004
6. Transparency International Corruption Perception Index 2003
7. World Bank, World Development Report 2002
8. UNESCO, Institute for Statistics
9. EIS, European Innovation Scoreboard 2003
10. www.indexmundi.com/taiwan/life_expectancy_at_birth.html
11. www.nu.hu
12. www.worldlanguage.com
13. www.phrasebase.com
14. www.nationmaster.com
15. www.business.nsw.gov.au
16. www.serenate.org
17. www.cepd.gov.tw
18. <http://www.nsf.gov> - Science and Engineering Indicators–2002
19. UNIDO Scoreboard Database, Industrial Development Report – 2002/2003
20. DTI - http://www.innovation.gov.uk/projects/rd_scoreboard/database/databasefr.htm
21. UNCTAD, United Nations of Trade and Development
22. www.uneca.org
23. The ISO Survey of ISO 9000 & ISO 14000 Certificates
24. OECD Patent Database, July 2003
25. US Patent and Trademark Office, March 2004
26. OHIM, Office for Harmonization in the Internal Market
27. www.mof.gov.tw

The 29 relevant variables/indicators listed above were transformed using a standardization procedure. The next step was the aggregation of the variables into each dimension. Similar weights were used for all the variables, with the exceptions noted in table 1 above, of two or three single indicators being aggregated into another indicator. In these cases the aggregated outcome counted as just one indicator. Overall 24 resulting indicators were aggregated into the NIS dimensions generating eight composite indicators.

We must clarify that in general each variable/indicator covered all the 69 countries in the sample, even though in a very few cases the data base that was built presented missing values. In those cases the composite measure of each NIS dimension was calculated for the country whose data was missing on the basis of only $n-1$ (or $n-m$, more generally) indicators.

In what regards country selection we tried to gather information covering both the advanced economies (large and small) and the catching up and developing economies. All the OECD economies were included, plus the EU members and candidate countries. All the Asian “tigers” were included, even though not all of them are properly “nations”. For the rest, the criterion was that the selected countries should have at least 20 million inhabitants. In this way we could assure that the analysis covered a great part of the world population. On the whole these countries stand for approximately 87.4% of the world population.

Having gathered, processed, summarised and critically observed all the necessary information, we were able to represent the results for each dimension along eight axes, using the so-called radar-type charts. We will present in subsection 4.2 below the graphical results of the exercise.

4. Data analysis

This section starts with a presentation of a cluster analysis done on the eight NISs dimensions for the 69 countries in the sample. Next those dimensions will be displayed

graphically for the different NISs in accordance to the cluster structure deriving from the previous cluster analysis.

4.1. Cluster analysis

The analysis we will now describe aimed at aggregating the different economies we are studying into relatively homogenous groupings of closely related NISs. The data used in this exercise is inscribed in a matrix that has the 69 countries in the sample as its individual “cases” and the eight NIS dimensions (determined through the steps described above) as the “variables” to be analysed.

Cluster analysis starts by aggregating cases with closer characteristics into basic clusters, and goes through a process of successive stages to aggregate relatively more dissimilar cases into larger clusters up to a final stage in which all cases, regardless of their differences, are aggregated into a single group. In the exercise we are undertaking the process of agglomerating individual countries up to that final stage took 68 steps (see the “agglomeration schedule” in the annexes) and it produced quite different sorts of countries’ groupings along the sequential stages.

The decision of deciding in which stage of the aggregation process one should stop, thus deciding the number of clusters to retain, depends on indications from the cluster analysis statistical output together with the personal judgement of the researcher. In the present case, based upon the analysis of the data provided by the clustering process, we decided to work with a three level structure of clusters, which for the sake of simplicity we will refer to as “megaclusters”, “clusters” and “subclusters”. Each megacluster comprises one or several clusters, while on its turn each cluster comprises one or several subclusters. This structure is presented in table 2 and stems from the dendrogram presented as an annex in the end of the paper.

Table 2. The cluster structure

MEGACLUSTERS	CLUSTERS	SUBCLUSTERS	Groups of Countries
M.0. Hong-Kong	C.0		G1
			→
M.1.	C.1.1		G2
	Ireland + Netherlands + Switzerland + Finland + Singapore + Sweden		→
	C.1.2	Germany + UK + France + Italy + South Korea + Taiwan S.C.1.2.1	G3
		U.S. + Japan S.C.1.2.2	G4
		Canada + Norway + Australia + Austria + New Zealand + Spain S.C.1.2.3	G5
	Denmark Belgium Luxembourg		G6
			→
M.2.	C.2.1	Portugal + Greece + Poland + Hungary + Czech R. + Slovenia S.C.2.1.1	G7
		Malaysia + Malta S.C.2.1.2	G8
		Latvia + Estonia + Lithuania + Slovak R. + Ukraine S.C.2.1.3	G9
	C.2.2	Russia S.C.2.2.1	G10
		China + Brazil + South Africa + Thailand + Argentina + India + Mexico S.C.2.2.1	G11
		Turkey + Colombia + Bulgaria + Indonesia + Philippines + Peru + Romania S.C.2.2.3	G12
		Egypt + Cyprus + Chile + Venezuela S.C.2.2.4	G13
	C.2.3	Algeria+Vietnam+Iran+Morocco+Bangladesh S.C.2.3.1	G14
		Pakistan+Kenya+Ethiopia+Myanmar+Tanzania+Sudan+Nigeria+ D.R. Congo S.C.2.3.2	G15

The information contained in table 2 above gives some hints about the global logic underlying the clustering process and about the three-level structure we decided to retain. Even though the interpretation of these results will be pursued deeply in the next

section, by looking at both the data concerning the eight NIS dimensions and the statistical output of the cluster analysis, we can already provide some remarks that will help to clarify the three-level structure displayed in the previous table.

Overall three megaclusters were generated, two with a very large number of cases each and a third one with just an individual case (Hong Kong).³ The two larger megaclusters, the first with 23 innovation systems, and the second with 45 countries, reflect the greatest divide in our study: megacluster 1 contains the developed (or “mature”) innovation systems, while megacluster 2 contains the developing (or “forming”) innovation systems.

Each of the two larger megaclusters is formed by three individual clusters. These clusters in turn contain between 1 and 4 subclusters each. Finally the 15 subclusters that were generated in this way agglomerate on average more than 4 cases each (in practice this means a variation between 1 and 8 cases).

Looking at the individual NISs into these different groupings, we have attempted at providing a classification for each of the six clusters that were constituted. The classification presented in table 3 below stems both from the observation of the cluster analysis’ results and from previous general knowledge about each of the economies in our study.

³ This economy resisted agglomeration into larger clusters up to the final stage of the clustering process. This is a direct result of an innovation system that overall seems to perform quite well but that displays some very peculiar characteristics (an extremely high “external communication” rating, but weak values for “institutional conditions” and particularly for “knowledge”).

Table 3. NISs classification

Megacluster 1 – Developed NIS	Cluster 1.1 – Dynamic innovation systems
	Cluster 1.2 – Performing innovation systems
	Cluster 1.3 – Unevenly developed NISs
Megacluster 2 – Developing NIS	Cluster 2.1 – Catching up NISs
	Cluster 2.2 – Hesitating NISs
	Cluster 2.3 – Unformed NISs

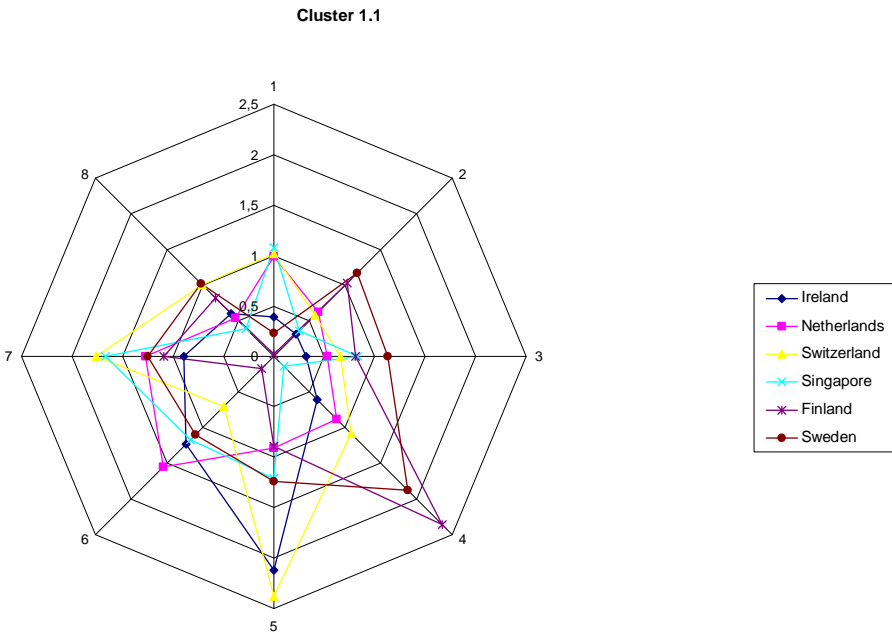
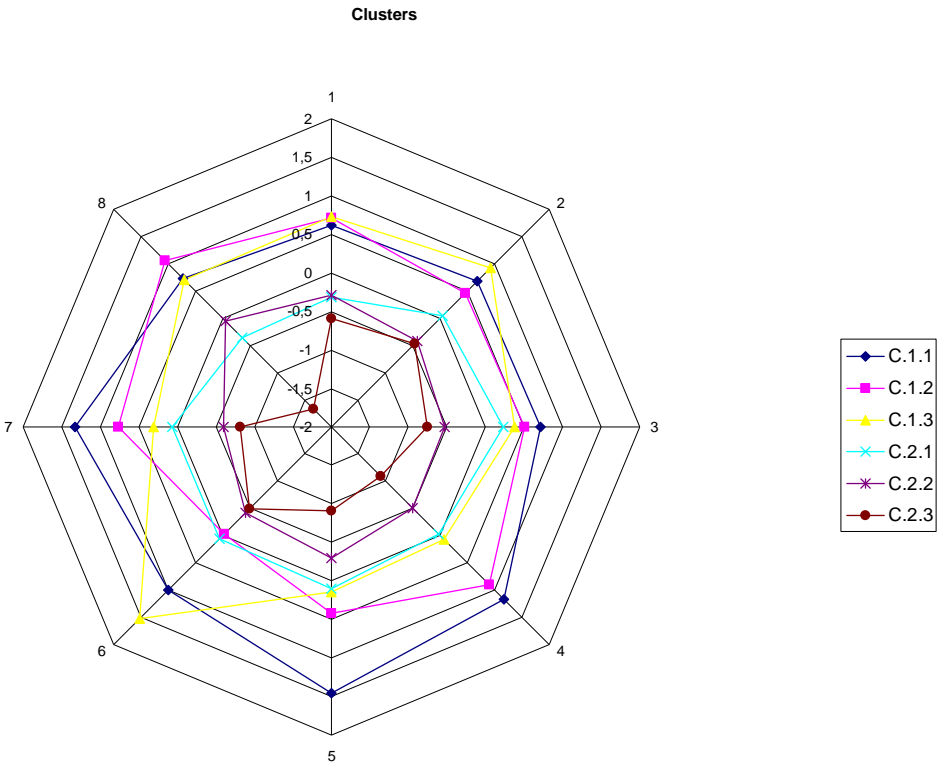
4.2. Mapping NISs (dimensions, size, ranking)

Having gathered, processed, summarised and critically observed all the necessary information, we are now able to represent the results for each NIS dimension along eight axes, using the so-called radar-type charts. This sort of graphic representation has many advantages. Information visualisation is often a neglected aspect of academic communication. However, from the point of view of social science users such as policy makers, seeing information may allow clearer interpretation of trends, more effective identification of anomalies and faster decision-making. With so many institutions generating huge quantities of data, images constitute a easy way to absorb information. Techniques for capturing vast amounts of information in one picture are likely to be in great demand from individuals for which time and attention are the scarcest of resources.

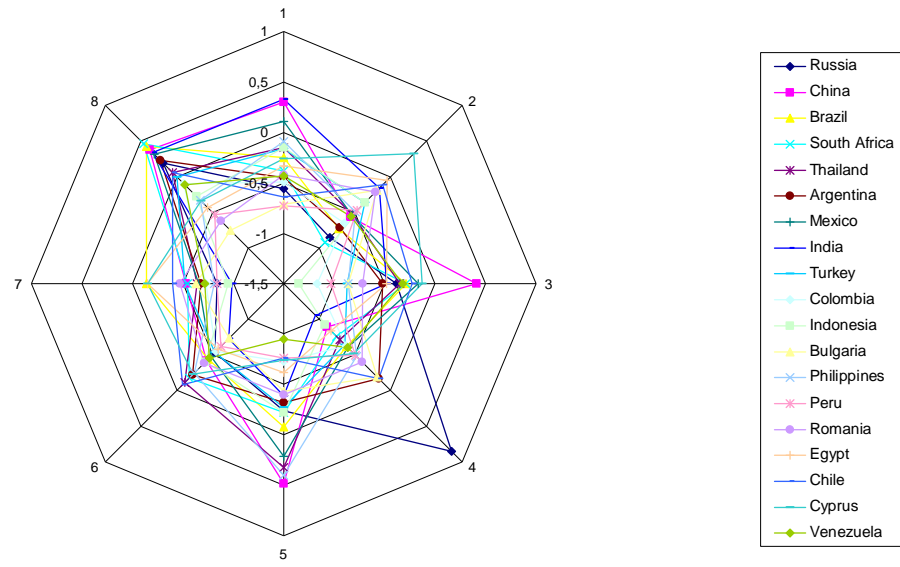
We could have presented the charts we will be now showing before the cluster nalaysis, but we are doing it now because in this way we can compare countries in the same cluster groupings. As an alternative, we might for example have presented countries belonging to the same continent or economic region in different graphs.

The radar-type charts are based on a matrix similar to the one shown in table 5 below but with figures also for individual countries. Each axis in the chart varies around zero (e.g. between -3 and 3), being zero an equivalent to the standardized means. The charts are illustrative of the relatively stronger and weaker points of each system and the

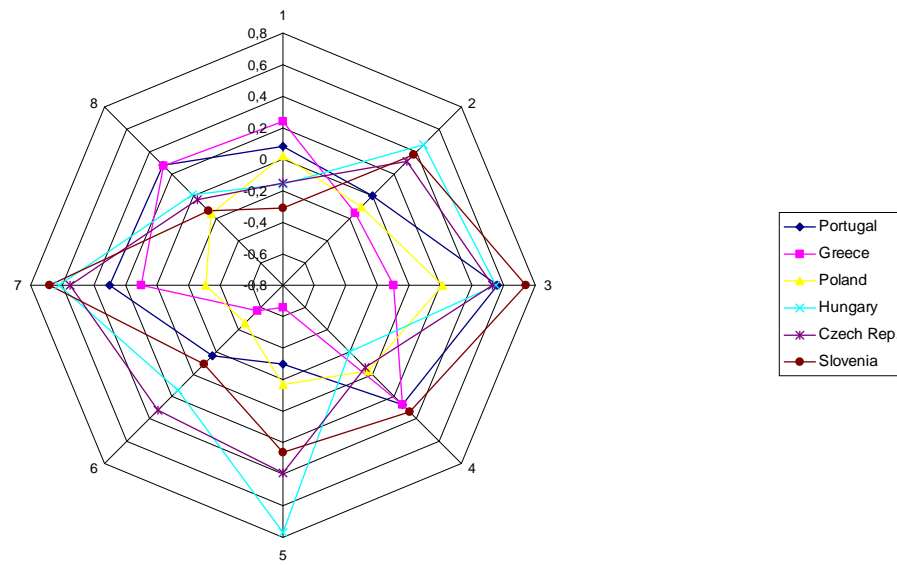
cluster groups they belong to. For the sake of pragmatism we are presenting below just a few charts of the more than two dozens that were built, to exemplify the potentialities of the technique.

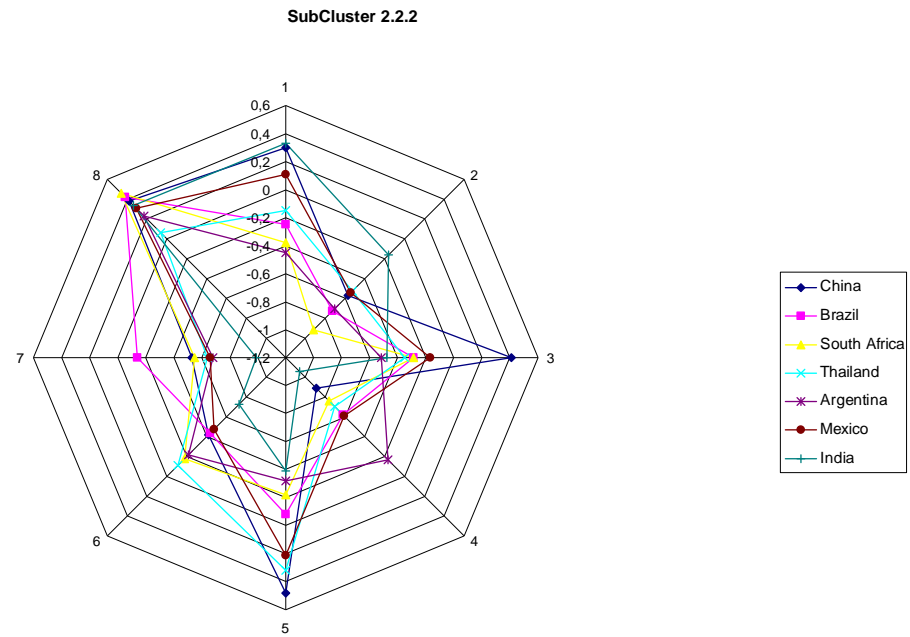


Cluster 2.2



SubCluster 2.1.1





The information in the previous figures allows one to estimate for each NIS both its “size” and discuss its uneven vs. balanced nature. NIS size, or total NIS dimension, might be calculated as the area within the line that represents each country in the chart. However, a simpler way of doing this is by calculating the mean of the values each country displays on the eight NIS dimensions. For the countries in the sample the values stemming from this calculation have the same relative distribution as the areas in the charts. A NISs ranking produced through these steps is presented in table 2 below.

Table 4. NIS ranking

1. Switzerland	1,15	24. Hungary	0,27	47. India	-0,39
2. Sweden	1,13	25. Czech R.	0,23	48. Turkey	-0,42
3. Netherlands	0,91	26. Slovenia	0,23	49. Ukraine	-0,43
4. Denmark	0,90	27. New Zealand	0,21	50. Egypt	-0,43
5. Finland	0,90	28. Portugal	0,13	51. Romania	-0,45
6. Hong Kong	0,90	29. Malta	0,05	52. Venezuela	-0,52
7. United Kingdom	0,88	30. Malaysia	0,05	53. Bulgaria	-0,56
8. United States	0,86	31. Slovak R.	0,00	54. Indonesia	-0,58
9. Singapore	0,86	32. Greece	-0,07	55. Morocco	-0,59
10. Japan	0,85	33. China	-0,10	56. Viet Nam	-0,59
11. Germany	0,81	34. Estonia	-0,11	57. Colombia	-0,63
12. Ireland	0,81	35. Poland	-0,12	58. Algeria	-0,67
13. Korea (R. of)	0,67	36. Mexico	-0,23	59. Peru	-0,68
14. France	0,62	37. Cyprus	-0,26	60. Iran (I.R.)	-0,75
15. Taiwan	0,60	38. Thailand	-0,26	61. Bangladesh	-0,77
16. Austria	0,57	39. Brazil	-0,27	62. Pakistan	-0,82
17. Norway	0,51	40. Lithuania	-0,29	63. Nigeria	-0,89
18. Belgium	0,50	41. Chile	-0,29	64. Kenya	-0,94
19. Spain	0,50	42. Russia	-0,30	65. Ethiopia	-0,97
20. Canada	0,44	43. Latvia	-0,30	66. Myanmar	-0,98
21. Italy	0,44	44. Argentina	-0,35	67. Tanzania	-0,99
22. Austrália	0,40	45. South Africa	-0,35	68. D.R. Congo	-1,05
23. Luxembou	0,38	46. Philippines	-0,36	69. Sudan	-1,06

The discussion of the unevenness of the system can be done by simply observing the charts to see whether the country has a regular shape with all eight dimensions showing a similar length, or otherwise it can be calculated as the standard deviation of the country's values in each of the eight axes. We are not presenting here figures for this, but in Godinho et al. (2003) we have exemplified this process.

5. Interpretation of the cluster structure (levels 1, 2 and 3)

The interpretation we will suggest now of the general patterns presented in section 4.1 above is based on the analysis of data concerning each of the three-level cluster structure. That data stemmed from the agglomeration process of cluster analysis. Further, for each group, regardless of being a megacluster, a cluster or a subcluster, the mean values and the standard deviation for the eight dimensions of the innovation systems were calculated. This facilitates the understanding of what are the strongest and

weaker dimensions in each group, together with providing information about the variation within the group⁴ (see table 5 below, just with the mean values).

The main lesson we draw from such analysis is that the three dimensions that most differentiate the different types of groups we are working with are *innovation*, *diffusion* and *knowledge*. In contrast, the factors associated with the five remaining dimensions we have considered as characterizing innovation systems, which include *market conditions*, *institutional conditions*, *intangible and tangible investment*, *economic structure* and *external communication*, normally play a much smaller role in explaining the overall differences between groups.

Starting the analysis with the two larger megaclusters, it is very clear that the “Developed NISs” perform very well on all the former three dimensions, while the “Developing NISs” show a very poor record on them. Observing the figures for those three dimensions presented in table 5 below, they show mean values of around +.9 for Megaccluster 1 and very contrasting values of only about -.5 for Megaccluster 2 (to interpret adequately these results it is convenient to recall that we are operating with standardised variables).

We will now concentrate first the analysis on clusters in Megaccluster 1, and next we will turn to clusters in Megaccluster 1.

⁴ Smaller standard deviations mean that all countries share the same characteristic with the same intensity, while higher standard deviations have the opposite meaning.

Table 5. Clusters' performance along the eight NIS dimensions Values

	AXIS 1	AXIS 2	AXIS 3	AXIS 4	AXIS 5	AXIS 6	AXIS 7	AXIS 8	AXES 1-to-8
M0	1,38	0,1	0,37	-0,5	0,67	3,38	1,08	0,68	0,9
M1	0,6886	0,5724	0,5416	0,8556	0,6537	0,4368	0,8525	0,9263	0,691
M2	-0,3842	-0,3081	-0,3765	-0,5426	-0,3604	-0,3049	-0,4719	-0,6102	-0,4198
C.1.1	0,6207	0,6766	0,7131	1,1585	1,45585	0,9855	1,3224	0,7272	0,9578
C.1.2	0,7093	0,4526	0,5045	0,8958	0,4177	-0,0301	0,7687	1,05988	0,5973
C.1.3	0,7279	0,9233	0,3717	0,062	0,1455	1,5183	0,3039	0,7013	0,5942
C.2.1	-0,313	0,0358	0,2314	-0,0321	0,1032	0,0478	0,0607	-0,3578	-0,028
C.2.2	-0,2879	-0,4293	-0,531	-0,5181	-0,301	-0,4171	-0,5996	-0,0541	-0,3923
C.2.3	-0,5959	-0,4748	-0,7585	-1,0889	-0,9109	-0,4935	-0,818	-1,6756	-0,852
S.C.1.2.1	0,9976	0,2769	0,4212	0,6971	0,7876	0,1809	0,8052	1,1874	0,6693
S.C.1.2.2	1,5618	0,4895	0,7883	1,0288	1,2861	-0,678	0,7431	1,6306	0,8562
S.C.1.2.3	0,1369	0,616	0,4933	1,0502	-0,2416	-0,0251	0,7408	0,7418	0,439
S.C.2.1.1	-0,0463	0,1476	0,4165	0,0986	0,0488	-0,1379	0,322	0,0405	0,1112
S.C.2.1.2	-0,1184	-0,0632	-0,1007	-0,7225	0,8314	0,5902	0,1353	-0,1506	0,0502
S.C.2.1.3	-0,711	-0,0589	0,1422	0,873	-0,1226	0,0538	-0,2827	-0,9187	-0,2263
S.C.2.2.1	-0,56	-0,85	-0,38	0,85	-0,24	-0,53	-0,84	0,19	-0,3
S.C.2.2.2	-0,0716	-0,5951	-0,2409	-0,6878	-0,0008	-0,3664	-0,5975	0,3152	-0,2806
S.C.2.2.3	-0,3936	-0,3902	-0,9799	-0,5338	-0,3424	-0,4967	-0,7073	-0,3726	-0,5271
S.C.2.2.4	-0,4129	-0,1012	-0,2905	-0,5357	-0,769	-0,3382	-0,3551	-0,204	-0,3758
S.C.2.3.1	-0,3478	-0,2966	-0,059	-0,8727	-0,8366	-0,439	-0,7775	-1,7666	-0,6745
S.C.2.3.2	-0,751	-0,5862	-1,1956	-1,224	-0,9574	-0,5275	-0,8434	-1,6187	-0,963

Megacluster 1

The analysis of clusters 1.1, 1.2 and 1.3 shows strong contrasting patterns in what concerns *innovation* and *diffusion*, as it happened in relation to the overall differences between megaclusters 1 and 2. Cluster 1.1 performs very well in *diffusion* (+1.3) but not so well in *innovation* (+0.7), while the opposite happens with cluster 1.2 (+0.8 and +1.1, respectively) and, to increase further the contrasts within megacluster 1, cluster 1.3 shows a relatively poor performance simultaneously in *innovation* (+0.7) and *diffusion* (+0.3). There are some other dimensions, however, in which the three clusters reveal results that deserve to be singled out. That is the case of cluster 1.1 that shows values much higher than the whole sample average in *economic structure* (+1.5) and in *knowledge* (+1.2). Cluster 1.2 is good in *knowledge* (+0.9) but performs very badly in *external communication*. This contrasts strongly with cluster 1.3 that precisely shows strong results in *external communication*. This third cluster has also a relatively weak record in *knowledge* (+0.1) even though this cluster's countries display quite distinct behaviours on this dimension. Moreover, this third cluster of the “developed NISs” megacluster reveals an excellent performance in *external communication* (+1.5), which

certainly relates to the small size of its members and to their integration in the EU market. Yet in terms of country size, one shall note that cluster 1.1 is made up of relatively small countries, while many of the 14 countries in cluster 1.2 are large or very large regardless of taking into consideration population, GDP or geographic size criteria.

We will now deepen the analysis of cluster 1.2 which according to the cluster analysis results presented before divides itself into three subclusters. The groups that were obtained are very interesting both in their coherence and in some contrasting characteristics that define them. Subcluster 1.2.1 contains the 4 largest EU economies, together with South Korea and Taiwan. The innovation systems of these economies are characterised by certain evenness, with values relatively similar over the 8 NIS dimensions. Exceptions to that evenness are *innovation* performance that on average is very good (+1.2) and *institutional conditions* that on the opposite seems to be faltering (only +0.3, this may derive among other aspects from aging populations).

Subcluster 1.2.2 contains the two largest OECD economies, the US and Japan. Their innovation systems emerge has much more uneven than those of the former group. They excel in *innovation* and in *market conditions* (both +1.6) and they also show good results in *economic structure* (+1.3) and in *knowledge* (+1.0). In contrast, they do relatively less well in *institutional conditions* (+0.5) and particularly in the *external communication* dimension, in which they present an extremely low value of -0.7. Some of these results might be surprising but that does not mean one can not account for them. In fact, as these two countries have very large domestic economies (revealed in the *market conditions* values), that might make *external communication* a less important requirement for the adequate functioning of their innovation systems.

Turning to the last subcluster of cluster 1.2, the group of countries that cluster analysis aggregated into this cluster, which at first sight might seem paradoxical, also has its own coherence. Two countries with very extensive unpopulated territories (Canada and Australia) were aggregated with two economies which share a peripheral nature (New Zealand and Norway, in the extreme Northwest of Scandinavia). But a further element ties these four countries together: they all share an international specialization in which natural resources and primary productions have a prominent role. This might account

for their not so good performance in the *economic structure* dimension (-0.2). And it also allows one to understand why Spain appears in this subcluster: the extension of the tourism industry in this country might be understood as a partial result of her natural resources endowment (sun and beaches).

Megacluster 2

We will now move to the analysis of Megacluster 2. The 45 countries in this megacluster are distributed between 3 clusters. Again *innovation* and *diffusion* are the dimensions along which these 3 clusters differentiate. Cluster 2.1, classified as “catching up NIS” in the previous section, reveals a poor performance in *innovation* (-0.4) but does relatively much better in *diffusion* (+0.2). Exactly the opposite happens with cluster 2.2, classified as “hesitating NIS”, that shows a performance in *innovation* closer to the whole sample average (-0.1) but a much poorer performance in *diffusion* (-0.6). Finally, cluster 2.3, that comprises the countries of “unformed NIS”, performs badly both on *diffusion* (-1.1) and much particularly on *innovation* (-1.7). It is interesting to note that the “catching up NIS” do well in *intangible and tangible investment* (+0.2) but have weaker *market conditions* (-0.3).

The subclusters of cluster 2.1 are all uneven, with some NIS dimensions relatively much better than others. Subcluster 2.1.1 comprises two small Southern European countries (Portugal and Greece) and four Central European countries (Slovenia, Czech Republic, Hungary and Poland). They all do well in *diffusion* (+0.3) and in *innovation* even tough to a minor degree in this second dimension (+0.04). The next two subclusters do less well in both *innovation* and *diffusion* (respectively -0.2 and +0.1 for subcluster 2.1.2 and -0.9 and -0.3 for subcluster 2.1.3). Subcluster 2.1.2 has a small number of countries (Malaysia and Malta) which have in common a good *economic structure* (+0.8) and good *external communication* (+0.6), but does badly in other dimensions, particularly in *knowledge* (-0.7). Finally subcluster 2.1.3 shows weak *market conditions* (-0.7) in consonance with the small size of the Baltic republics that are its members.

Cluster 2.2 comprises 4 relatively distinct subclusters. The first subcluster has just one country – Russia – that resisted almost to the last stages of the clustering process to integrate other clusters. In this perspective, Russia is similar to Hong Kong: this country

also has a very idiosyncratic and uneven NIS. In fact, Russia displays a good result in the *innovation* dimension (+0.9) but a symmetrical and similarly impressive result is recorded in *institutional conditions* (-0.9). If this latter dimension were less bad, one might conjecture that Russia could have joined the former cluster of the “catching up NIS” at it happened for example with Ukraine.⁵

The next subcluster is particularly important. In fact, its constituent countries make up almost 45% of the world population and it comprises the most important emerging economies: China, India, Brazil, Mexico and South Africa.⁶ They all do relatively well in *innovation* (+0.3), even better than any other subcluster of cluster 2.1. They show however weak performances in *knowledge* (-0.7) and in *institutional conditions* (-.06). Further, in line with the overall size of their economies, they show *market conditions* above what might be expected. The unevenness of the NISs that characterizes this subcluster only reveals the strong dualism of many of the countries that are its constituents. As a matter of fact, modern advanced sectors operate in parallel with outdated technologies and processes that still dominate extensive segments of these countries’ economies.

The last two subclusters of cluster 2.2 reveal on average a much weaker performance than the previous two subclusters. In fact, all the values exhibited in the eight dimensions characterising their NISs are negative. However, one shall note the configuration of these NISs, in particular that of subcluster 2.2.3, is much more even than that of subclusters 2.2.1 and 2.2.2. Despite that, stronger and weaker points still emerge in the analysis. Subcluster 2.2.3 has its most important fragilities in *intangible and tangible investment* (-1.0) and in *diffusion* (-0.7), while subcluster 2.2.4 has its weakest point in *economic structure* (-0.8). Given the weaknesses they display, countries in both these two subclusters risk strongly to fall down to cluster 2.3. This is the reason why cluster 2.2 was given the “oscillating NIS” classification: some of its countries might well move forward to the “catching up NIS” group and even envisage in the longer term to reach the “developed NIS” status of megacluster 1, but many of its

⁵ Note however that Russia has a higher positioning than Ukraine in the overall NIS ranking presented before.

⁶ Thailand and Argentina are also part of subcluster 2.2.2.

members also risk to get stuck in the vicious circles of underdevelopment and fall further below their current levels.

Finally on this analysis and interpretation of the three-level cluster structure that was proposed, we concentrate on cluster 2.3, which was classified as of “unformed NIS”. This designation has to do with the fact that in this cluster one does not detect signs of innovation activities or of any type of organization that might deserve the “system” classification. However, two situations in cluster 2.3 are detectable and they have to do with subclusters 2.3.1 and 2.3.2. On average countries in the former subcluster perform better than countries in the latter. This may represent an attempt of the former countries of escaping the traps we have mentioned above. In doing so and with a value that is close to the overall sample average (-0.1) the *intangible and tangible investment* dimension might testify those efforts. Also their performance in *institutional conditions* is not dramatically negative. In the second subcluster, however, the situation is in general bleaker on all dimensions and the mapping of their performances provides strong indications of a structural endemic crisis in these countries.

6. Conclusion: Towards a NISs taxonomy

The analysis developed above will now be re-examined. First we will concentrate on the method that has been suggested for mapping national innovation systems. Next we will return to the results of the clustering exercise, which was carried out in order to helping us to envisage a NISs taxonomy. Finally, we conclude with some remarks on the normative implications and elaborate on further research needs in this area.

Some conclusions regarding the NIS mapping technique

The exercise that was carried out shows that the NIS mapping technique we have deployed although simple in the steps it requires has significant analytical potential. In what regards the analytical value, we are aware that different arguments may be raised in relation to the process that led us to the identification of eight major NIS dimensions. Even though we think those dimensions are sound and credible, we think that what is strategically more important is the process involved in their definition. This is so

because by getting involved in that process one is forced to be specific about what exactly is meant by “national innovation system”, concentrating on the aspects that deserve to be analysed with greater attention. Such process might help the conceptual work in this area to evolve further in the future, moving out of vague discussions to more precise definitions of “NIS” and its components.

A possible NIS taxonomy

The cluster analysis that was implemented and that has been interpreted in sections 4 and 5 produced a break-down of the 69 countries in the sample into a three level structure: two large megaclusters; six clusters; and fifteen subclusters. Such break-down provides ground for a possible NISs taxonomy. What are thus the major lines separating the different NISs groupings to which cluster analysis led us to? We saw that what differentiates most the countries in the sample is their performance in three critical dimensions of the innovation systems: *innovation*, *diffusion* and (but to a lesser extent) *knowledge*. These dimensions separated clearly countries in megacluster 1 from those in megacluster 2. Moreover, within each megacluster, and even between certain subclusters, it was possible to detect strong behavioural differences along the previous first two dimensions.

Another aspect that emerged as important in differentiating both clusters and subclusters is the overall country size, namely with regard to GDP and population numbers. In fact, we noticed that very large countries tend to cluster together. That was the case of US and Japan, but also of China, India, Brazil, Mexico and South Africa. And the fact that Russia resisted agglomeration is also an indication that large countries have certain specificities that separate them from the remaining countries. In contrast, smaller and medium size economies tended to agglomerate in certain clusters or subclusters, showing on average better performances in *external communication* but not so good performances in *market conditions*, which is where normally larger countries tend to perform relatively better. These two dimensions emerge therefore as partial substitutes in connection to country size.

Finally, an additional aspect that surfaced as relevant is the endowment of countries in natural resources. This was clear in the case of some “developed NISs” for which such

endowments (being them minerals, forests, good grazing lands or sun and beaches) seem to be acting in practice as partial substitutes of other critical dimensions and providing a dynamism revealed in these countries' positioning in the overall NISs ranking.

Table 6 below suggests a synthesis of our analysis, in terms of a possible taxonomy of innovation systems and the factors that affect the localisation of countries in “NIS space”. The white cells indicate the positions in which typically one might find the different NISs, given the major dimensions referred to above that drive the differentiation of innovation systems plus the critical contingency factors. The taxonomy that is proposed has six main types of countries plus two additional minor groups, stemming the latter groups from possible good endowments in natural resources.

Table 6. A taxonomy of national innovation systems based on the localisation of countries in “NIS space”

			Critical dimensions (Innovation, Diffusion...)					
			Absolute high values			Absolute Low values		
			Megaclusters					
			M. 0, M. 1			M. 2		
			Clusters and subclusters					
			Relatively High in Innovation and Low in Diffusion	Relatively Low in Innovation and High in Diffusion	Relatively Low in both Innovation and Diffusion	Relatively High in Innovation and Low in Diffusion	Relatively Low in Innovation and High in Diffusion	Relatively Low in both Innovation and Diffusion
Critical contingency factors	Country Size	Large/ /Very large	C.1.2			C.2.2.		
		Small/ /medium		C.1.1	C.1.3 ↓(DK)		C.2.1	C.2.3
	Good natural resources endowment				Sub. 1.2.3			↑(Nigeria)

Normative implications and further research

In what concerns the practical policy-making dimension, the cartography of NISs that was produced through the method put forward, together with its associated indicators and the taxonomy we have drawn above, indisputably show high potential. In this respect, it is clear that our work follows in line with some key recommendations of the innovation systems research: «Concrete empirical and comparative analyses are absolutely necessary for the design of specific policies in the fields of R&D and innovation. The S[systems of] I[nnovation] approach is an analytical framework suited for such analyses. It is appropriate for this purpose because it places innovation at the very centre of focus and because it is able to capture differences between systems. In this way specific problems that should be objects of innovation policy can be identified.» (Edquist 2002, p. 22).

On the policy side we must also recall here the conclusions of a OECD project on “Dynamising National Innovation Systems”: «the need to engage in effective learning

processes suggests that governments may benefit from intensified international benchmarking of policy practices in this [NIS] respect» (OECD 2002, p. 81).

In conclusion, it becomes clear that the mapping tool that was implemented fits well into the type of comparative and benchmarking analyses that have been sought both by academics and policy-makers. This tool has the advantage of avoiding the oversimplification that has been associated with many recent scoreboard exercises, which have tended to sum up the analysis to single summary measures of innovation. In contrast, our method allows for a clear identification of the weakest and strongest dimensions of each NIS. Moreover, and as it was shown, this tool and the resulting taxonomy have policy-making value for both the advanced countries, the intermediate catching up countries and the developing economies as well.

To finalise with we must say that besides eventual disagreements that may arise in what concerns the definition of the NIS dimensions etc., an aspect that we are aware is the incompleteness of the present exercise in terms of several key indicators that are lacking. Among others, there are three key areas in which indicators do not exist for such a larger sample as the one we were dealing with. First, there is no comprehensive and updated data for the nature of the R&D activities in many countries, detailing the share of business in total GERD or identifying the relative weight of basic and applied R&D. Second, the number of indicators regarding *innovation* we can mobilise for a comparative exercise like the present one is still very limited. Surveys like CIS in Europe needed to be promoted in other continents as well to supply indicators about the outputs of the innovation process. In Latin America a good deal of work on this has been done, and a revised version of the Bogotá Manual has been announced. This together with the expected new version of the Oslo Manual might be an impulse for a wider and globally more planned establishment of innovation surveys. Finally, a third area in which we critically need information is about the type and quality of interactions established within the innovation systems. Indicators such as “Business funding of government and university R&D”, “R&D arrangements between firms and university or Research and Technology Organizations”, or yet “SMEs in cooperation to innovate” are critically needed so that a better characterization of innovation systems might advance further.

References

- Amable, B., R. Barré and R. Boyer (1997) Les Systèmes d'Innovation à l'Ère de la Globalisation. Paris : Economica.
- Arundel, A. (2001) Innovation Scoreboards: Promises, Pitfalls and Policy Applications, in B. Thuriaux, E. Arnold and C. Couchot (Eds.) Innovation and Enterprise Creation, Statistics and Indicators, European Commission, Directorate General for Enterprise EUR 17038, pp 246-251.
- Asheim, B. and Gertler, M. (2004) Regional systems of innovation, in J. Fagerberg, D.C. Mowery and R.R. Nelson (eds.), The Oxford Handbook of Innovation. Oxford: Oxford University Press.
- Autio, E. and T. Laamanen (1995) Measurement and Evaluation of Technology Transfer: Review of Technology Transfer Mechanisms and Indicators, in Int. J. Technology Management, Vol. 10, Nos 7/8, pp. 643-664.
- Braczyk, H. J. et al. (1998) Regional Innovation Systems. UCL Press, London.
- Breschi, S. and F. Malerba (1997) Sectoral systems of innovation: technological regimes, Schumpeterian dynamics, and spatial boundaries, in C. Edquist (ed.), Systems of Innovation: Technologies, Institutions and Organization. London: Pinter.
- Carlsson, B. and R. Stankiewicz (1995) On the nature, function and composition of technological systems, in B. Carlsson (ed.), Technological Systems and Economic Performance: The Case of Factory Automation. Boston: Kluwer Academic Publishers.
- Carlsson, B. and S. Jacobsson (1997) In search of a useful technology policy – general lessons and key issues for policy makers, in Carlsson B. (ed.), Technological Systems and Industrial Dynamics. Boston: Kluwer Academic Publishers.
- Cassiolato, J.E., H. Lastres and M. L. Maciel (eds.) (2003) Systems of Innovation and Development: Evidence from Brazil. Cheltenham, UK: Edward Elgar Publishing.
- Cimoli, M. (ed.) (2000), Developing Innovation System: Mexico in the Global Context. New York and London: Continuum-Pinter.
- Cooke, P. (1998) Introduction. Origins of the concept, in Braczyk, H.-J. et. al. (Eds.), Regional Innovation Systems. London: UCL Press.
- David, P. and D. Foray (1995) Accessing and expanding the science and technology knowledge base, in STI Review, 16, pp. 13-68.
- Edquist, C. (2002) Innovation policy – A systemic approach. Paper presented to the IES Seminar, ISEG/UTLisbon.
- Evangelista, R., T. Sandven, G. Sirilli and K. Smith (1998), Measuring innovation in European industry, in International Journal of Economics and Business 3 (5), pp. 311-333.

Fagerberg, J. and M. Godinho (2004) Catching up and Innovation, in J. Fagerberg, D. Mowery and R. Nelson (eds.), *The Oxford Handbook of Innovation*. Oxford: Oxford University Press.

Freeman, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.

Freeman, C. (1979) The determinants of innovation, in *Futures*, June, 206-215.

Freeman, C. (2004) Technological infrastructure and international competitiveness, in *Industrial and Corporate Change*, Vol. 13, No. 3, pp. 551-69.

Freeman, C. and C. Perez (1988), Structural crisis of adjustment: business cycles and investment behaviour, in G. Dosi et al. (eds.), *Technical Change and Economic Theory*. London: Pinter.

Freeman, C. and L. Soete (1997) *The Economics of Industrial Innovation*. London: Pinter.

Godinho, M. M., S. Mendonça and T. S. Pereira (2003) Mapping Innovation Systems: a framework based on innovation surveys data, paper presented at the First Globelics Conference 'Innovation Systems and Development Strategies for the Third Millennium', Rio de Janeiro November, 2-6 Nov. 2003

Gregersen, B. and B. Johnson (2001) *Learning Economy, Innovation Systems and Development*, Paper prepared for the Converge Project ("Strategies and policies for systemic interactions and convergence in Europe – Converge").

Gu, Shulin (1997) China's National Innovation System Approach to Participating in Information Technology: The Innovative Recombination of Technological Capability, Discussion Paper Series 9701, INTECH, United Nations University.

Intarakumnerd, Patarapong (2004) Thailand national innovation system in transition, paper presented at the ASIALICS International Conference on "Innovation Systems and Clusters in Asia: Challenges and Regional Integration," 1-2 April 2004, at Bangkok, Thailand.

Kline, S.J. and N. Rosenberg (1986) An overview of innovation, in R. Landau and N. Rosenberg (eds.), *National Systems of Innovation*. Oxford University Press.

Krishnan, R. T. (2003) The Evolution of a Developing Country Innovation System During Economic Liberalization: The Case of India, paper presented at the First Globelics Conference 'Innovation Systems and Development Strategies for the Third Millennium' Rio de Janeiro November, 2-6 Nov. 2003

Landabaso, M. (1995), The promotion of innovation in Regional Community Policy: Lessons and proposal for a Regional Innovation Strategy, paper presented at the RESTPOR '95 Meeting.

- Lundvall, B.-A. (1985) *Product Innovation and User-Producer Interaction*. Aalborg: Aalborg University Press.
- Lundvall, B.-A. (ed.) (1992) *National Systems of Innovation - Towards a Theory of Innovation and Interactive Learning*. London: Pinter.
- Lundvall, B.-A. (2004) Introduction to 'Technological infrastructure and international competitiveness' by Christopher Freeman, in *Industrial and Corporate Change*, Vol. 13, No. 3, pp. 531-39.
- Lundvall, B.-Å. and S. Borràs (1999) *The Globalising Learning Economy: Implications for Innovation Policy*, Brussels, DG XII.
- Malerba, F. (2004) Sectoral Systems: How and Why Innovation Differs Across Sectors, in J. Fagerberg, D. Mowery and R. Nelson (eds.), *The Oxford Handbook of Innovation*. Oxford: Oxford University Press.
- Mendonça, S., T. S. Pereira and M. Godinho (2004) Trademarks as an innovation indicator, forthcoming in *Research Policy*.
- Meyer-Krahmer, F. et al. (1998) *Internationalisation of Research and Technology: Trends, Issues and Applications for Science and Technology in Europe*. Brussels: European Commission, ETAN Working Paper.
- Nelson, R. R. (ed.) (1993) *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.
- OECD (1992) *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: Oslo Manual*. Paris: OECD.
- OECD (2002), *Dynamising National Innovation Systems*. Paris: OECD.
- Patel, P. (1995) Localised production of technology for global markets, in *Cambridge Journal of Economics*, n° 19.
- Pavitt, K. (1984) Patterns of Technical Change: Towards a Taxonomy and a Theory, in *Research Policy*, 13, 343-74.
- Rush, H., M. Hobday and J. Bessant (1996) *Technology Institutes: Strategies for Best Practice*. Routledge.
- Saxenian, A. (1994) *Regional advantage: Culture and competition in Silicon Valley and route 128*. Cambridge, MA: Harvard University Press.
- Sinh, Bach Tan (2004) Transformation of Vietnam National System of Innovation: The case of organizational and policy learning in the industrial technology R&D institutes, paper presented at the ASIALICS International Conference on "Innovation Systems and Clusters in Asia: Challenges and Regional Integration," 1-2 April 2004, at Bangkok, Thailand.

Smith, K. (1992) Technological innovation indicators: experience and prospects, in *Science and Public Policy*, 19(6), 383-392.

Smith, K. (2004), *Measuring Innovation*, in J. Fagerberg, D. Mowery and R. Nelson (eds.), *The Oxford Handbook of Innovation*. Oxford: Oxford University Press.

Teubal, M., D. Foray, M. Justman and E. Zuscovitch (eds.) (1996) *Technological Infrastructure Policy: an International Perspective*. Kluwer Academic Publishers

Zanfei, A. (2000) Transnational firms and the changing organisation of innovative activities, in *Cambridge Journal of Economics*, 24, pp. 515-542.

Annexes

Annex 1. Cluster Analysis Agglomeration Schedule

Agglomeration Schedule						
Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	64	67	,193	0	0	7
2	24	25	,224	0	0	11
3	51	53	,320	0	0	16
4	36	38	,329	0	0	15
5	57	59	,331	0	0	16
6	39	45	,331	0	0	13
7	64	69	,408	1	0	22
8	40	43	,447	0	0	33
9	11	14	,466	0	0	31
10	37	50	,520	0	0	26
11	24	26	,572	2	0	50
12	48	54	,585	0	0	21
13	39	44	,623	6	0	15
14	16	19	,649	0	0	18
15	36	39	,761	4	13	38
16	51	57	,765	3	5	30
17	41	52	,773	0	0	26
18	16	20	,774	14	0	44
19	28	32	,814	0	0	23
20	22	27	,817	0	0	32
21	46	48	,827	0	12	30
22	63	64	,852	0	7	39
23	28	35	,873	19	0	50
24	8	10	1,001	0	0	54
25	55	58	1,008	0	0	27
26	37	41	1,032	10	17	42
27	55	60	1,048	25	0	41
28	31	34	1,090	0	0	33
29	3	9	1,145	0	0	55
30	46	51	1,186	21	16	42
31	11	13	1,191	9	0	36
32	17	22	1,270	0	20	44
33	31	40	1,276	28	8	51
34	65	68	1,323	0	0	47
35	29	30	1,330	0	0	57
36	7	11	1,368	0	31	40
37	2	5	1,445	0	0	63
38	33	36	1,465	0	15	43
39	62	63	1,501	0	22	45
40	7	15	1,560	36	0	52
41	55	56	1,567	27	0	53
42	37	46	1,669	26	30	49
43	33	47	1,730	38	0	49
44	16	17	1,847	18	32	62
45	62	66	1,916	39	0	47
46	1	12	2,071	0	0	55
47	62	65	2,094	45	34	56
48	4	18	2,197	0	0	60
49	33	37	2,202	43	42	58
50	24	28	2,278	11	23	57
51	31	49	2,443	33	0	59
52	7	21	2,467	40	0	54
53	55	61	2,497	41	0	56
54	7	8	2,754	52	24	62
55	1	3	2,768	46	29	63
56	55	62	3,135	53	47	66
57	24	29	3,216	50	35	59
58	33	42	3,366	49	0	61
59	24	31	3,439	57	51	61
60	4	23	3,622	48	0	65
61	24	33	4,139	59	58	66
62	7	16	4,349	54	44	64
63	1	2	5,199	55	37	64
64	1	7	5,777	63	62	65
65	1	4	6,521	64	60	67
66	24	55	6,821	61	56	68
67	1	6	13,684	65	0	68
68	1	24	15,427	67	66	0

Annex 2 - Cluster analysis dendrogram

[illegible]